Range Improvement Methods and Environmental Influences in the Northern Great Plains

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RANGE IMPROVEMENT METHODS AND ENVIRONMENTAL INFLUENCES IN THE NORTHERN GREAT PLAINS[1]

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SUMMARY

A study of seven methods or land treatments for forage improvement on native, mixed-prairie range was conducted near Miles City, Mont., from 1957 through 1962. The experimental treatments included protection from grazing, seeding, range pitting alone and with seeding of alfalfa and with nitrogen fertilization, and different rates of nitrogen fertilization. The treatments were applied in 2 successive years on four range sites that are common in eastern Montana and that had been either heavily or lightly grazed since 1932. The effects of treatments and interactions of year of application of treatments, weather, age of treatments, and stocking rates on herbage yields of major species and major plant groups and on crude protein content of total herbage were measured.

A 4-year period of decreasing precipitation culminating in severe drought and followed by a year of above-normal moisture was observed during the study.

The most immediately effective treatments for increasing desirable herbage production were single applications of both 30 and 90 pounds of nitrogen per acre on overflow range sites. Residual responses lasted for an additional 2 years. Over the long run, seeding crested wheatgrass was the most successful range improvement treatment. Yields on the seeding treatment initially decreased but later increased. Both 30 pounds of nitrogen on the overflow range site and seeding on the silty range site and the clayey range site were economically profitable. Yields increased on range pitting treatments and combinations on overflow and clayey range sites, but the responses were delayed. The rest treatment (protection from grazing) had little effect on yields.

In 1961 and 1962 yields increased on only the seeding treatment. Seeding was most successful on clayey range sites.

Yields increased most where the range improvement treatments had been applied in the fall of 1957, a year of favorable moisture at the beginning of a drought period. Where the treatments were applied in the fall of 1958, after the drought period had begun, yields on nearly all treatments, except seeding, either decreased or increased only slightly.

Past stocking rates influenced only the blue grama response to range improvement treatments. Yields of blue grama increased on several treatments on heavily grazed ranges, but not on lightly grazed.

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INTRODUCTION

Extensive acreages of native range in eastern Montana and adjacent areas in the Northern Great Plains have been seriously depleted over the past near-century of livestock grazing. Most require improvement measures to economically restore herbage yields to or above previous levels and to improve composition of desirable species.

Low and highly variable precipitation and heterogenous soils strongly influence success of nearly all range improvement treatments. These environmental influences may cause outright failure or may delay success for several years.

Previous studies in the region (Rogler and Lorenz *1957;* Barnes, Anderson, and Heerwagen *1958;* Whitman, Peterson, and Conlon *1961* and *1962;* Dubbs *1966;* Rauzi, Lang, and Painter *1968*) [3] have examined one or more treatments for range improvement, but rarely have the treatments been compared among themselves for success, adaptability to various soil types or sites, or rate of improvement under varying precipitation levels.

The purpose of this study was to compare several treatments and combinations of treatments for range improvement in eastern Montana. The effects of the treatments on yields of major species and major plant groups and on crude protein content of herbage were measured.

METHOD OF STUDY

The study areas were established on native range typical of the drier, southwestern part of the Northern Great Plains. The area has fewer midgrasses and more short grasses than the less arid Dakotas. The major species were the midgrasses—western wheatgrass (*Agropyron smithii* Rydb.), needle-and-thread grass (*Stipa comata* Trin. & Rupr.), and green needlegrass (*S. viridula* Trin.); the short grasses—blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.); and threadleaf sedge (*Carex filifolia* Nutt.). The major shrubs were big sagebrush (*Artemisia tridentata* Nutt.), silver sagebrush (*A. cana* Pursh.), and plains pricklypear (*Opuntia polyacantha* Haw.). Annual and forb species usually comprised only a minor part of the plant cover.

The experimental areas were located on the U.S. Range Livestock Experiment Station, approximately 7 miles south of Miles City, Mont. The plots were in pastures used in stocking rate studies continuously since 1932 (Reed and Peterson *1961;* Houston and Woodward *1966*).

The range improvement treatments studied were: (1) Rest—complete protection from livestock grazing; (2) seeding—late summer plowing and disking for standard seedbed preparation followed by late fall drilling of native western wheatgrass in 12-inch furrows; (3) pitting—range pitting with offset disk pitter (Barnes, Anderson, and Heerwagen *1958*); (4) pitting plus alfalfa—pitting followed by hand seeding of alfalfa (*Medicago sativa* L. cv. Ladak) in pits; (5) pitting plus 30 pounds of nitrogen per acre (30N)—pitting followed by a single fall broadcast application of 30 pounds of nitrogen fertilizer per acre (90 pounds per acre of 33.5 percent ammonium nitrate); (6) 30N—a single fall broadcast application of 30 pounds of nitrogen per acre; and (7) 90 pounds of nitrogen per acre (90N)—a single fall broadcast application of 90 pounds of nitrogen per acre (270 pounds per acre of 33.5 percent ammonium nitrate).

After the treatments were applied, all treatment areas were fenced to exclude grazing (fig. 1). The treatment results were compared with those on the grazed area outside the fenced exclosure.

The range improvement treatments were applied in duplicate in late fall of 2 successive years, 1957 and 1958, on both heavily and lightly stocked pastures on each of four range sites. Plot

[3] References to Literature Cited, p. 13, are indicated by name of the author or authors followed by year of publication in italic.

PN-1910

Figure 1.—View of pitted range on right and untreated range on left shortly after fencing to exclude livestock.

size was 12 by 20 feet. The heavily stocked pastures had been stocked at about 1.8 acres per animal-unit-month since 1932, and the lightly stocked pastures at about 3.2 acres. Because of severe drought in 1961, all grazing in the experimental pastures was terminated for the duration of the study.

The soils on the range sites were described by Parker as follows:[4]

Overflow range site. Lohmiller silty clay soil. Level, moderately well drained, light-colored, alluvial soil of Brown soil zone. Substrata of calcareous, thinly stratified alluvium of silty clay on nearly level stream terrace. In creek bottom. Often flooded during and after storms. Dominated by western wheatgrass, green needlegrass, and silver sagebrush.

Silty range site. Dooley fine, sandy loam soil. Gently sloping, well drained, moderately developed, sandy soil of Brown soil zone. Substratum of weak, prismatic, sandy clay loam. Distinctly calcareous horizon over deep, fine, sandy loam. Dominated by blue grama, big sagebrush, needleleaf sedge (*Carex eleocharis* L. H. Bailey), needle-and-thread grass, and plains pricklypear.

Clayey range site. Ferdig clay loam soil. Gently sloping, moderately to poorly drained, strongly solodized-solonetz of Brown and Chestnut soil zone developed in alluvium. Substrata grading from soft to hard blocky structure. Abundant sand and silt in upper layers. Gypsum crystals below calcium carbonate horizon. Dominated by blue grama with a scattering of western wheatgrass and threadleaf sedge.

Dense Clay range site. Marias silty clay soil. Level, poorly drained clay soil without horizon development, becoming hard, crusted, and cracking upon drying. Substrata of strongly alkaline, blocky structure. Gypsum crystals and lime seams common at medium depths. Dominated by western wheatgrass, a stunted form of big sagebrush, Sandberg bluegrass (*Poa secunda* Presl), and plains pricklypear.

All treatments were sampled by clipping to ground level four randomly located 1- by 2-foot plots in late July to early August each year. The grazed area outside the fenced exclosure at each location was sampled by clipping four 1- by 2-foot plots that were protected from grazing by small cages moved each year.

The treatments applied in the fall of 1957 were sampled for 5 years, through 1962, and those applied in the fall of 1958 were sampled for 4 years.

The herbage harvested from each plot was separated into western wheatgrass, blue grama, other perennial grasses including sedges, all annual and forb species, and alfalfa. Brush species and plains pricklypear were not harvested. After harvesting, all herbage from each treatment-replicate combination was combined for protein determinations.

In the fall of 1962, at the end of the study, soil nitrogen in the top 1 foot of soil was determined for treatments on the heavily stocked area of the silty range site.

Statistical analyses of data were made by analysis of variance using split-plot design. Replicate-blocks were major plots, treatments were subplots, and years of sampling were sub-subplots. Each year of treatment applications was analyzed separately.

[4] Parker, John. soil description and mapping units of experimental ranges, u.s. range livestock experiment station, miles city, mt. U.S. Soil Conserv. Serv. Rpt., 47 pp. 1964. [Correspondence to Station Director.]

RESULTS

Weather

Effective precipitation steadily decreased during the first 4 years of study (fig. 2). Spring precipitation (April–May–June) was low during the entire period. In 1957 precipitation was slightly above the long-term mean. Drought effects became evident in 1959. However, the most serious drought with a very low level of herbage yields was in 1961. In the fall of 1961 and spring of 1962 precipitation was substantially above normal, causing significant recovery in herbage production.

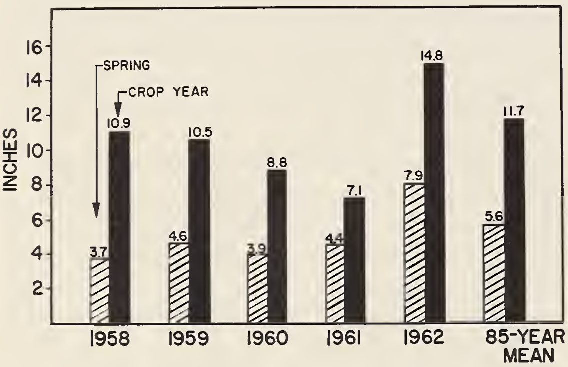

Figure 2.—Spring (April–June) and crop-year (preceding September-current July) precipitation at U.S. Range Livestock Experiment Station, Miles City, Mont., for the period 1958–62, with long-term means.

Weather influenced the major species and major plant groups differently on different sites or soils and herbage combinations. Weather was confounded with year of establishment and age of treatments. Yield responses to treatment were influenced not only by differences in soil moisture characteristics and drought effects between sites, but were influenced also by species of native herbage present, which were a result of the inherent herbage-soil-grazing relationships of the site.

Herbage Yields

Perennial forbs and alfalfa were a minor component of herbage yields, seldom contributing more than 10 pounds per acre on any treatment. The forbs were combined with annual species and the alfalfa component was ignored.

Overflow Range Site

The dominant feature of the overflow site was the occasional flooding. Yields of the cool-season western wheatgrass, a desirable and important species on these ranges, and total perennial grasses were higher on this site than on any other throughout the study (table 1).

On the treatments applied in 1957, before the drought had begun, yields of western wheatgrass increased significantly for 3 years on both the 30N and 90N treatments. Yields on all three pitting combinations increased during the second and third years after treatment. Yields on the rest treatment increased only during the second year. During the first 2 years after treatment, yields of western wheatgrass on the seeding treatment were significantly lower than on the grazing treatment. During the last 3 years of the study, yields on the seeding and grazing treatments were similar. In 1961, the year of severe drought, no treatment affected yields of western wheatgrass. In 1962, a year of substantially above-normal moisture, yields of western wheatgrass were substantially lower on the rest, pitting, pitting plus alfalfa, and 90N treatments than on the grazing treatment.

On all the treatments applied in 1958, after the drought had begun, no treatment increased yields of western wheatgrass.

Blue grama was scarce on the overflow range site and did not respond to any treatment.

On the treatments applied in 1958, after the drought had begun, yields of all perennial grasses, as a group, increased on only the 90N treatment and for only 2 years. These increased yields were due primarily to the response of green needlegrass on this site.

In most years, yields of annual and forb species increased significantly on the seeding treatment applied in both 1957 and 1958. These increased yields were due to invasion by these species on the areas bared by the plowing and disking operation and to the slow establishment of the seeded western wheatgrass. In 1962, increased yields of annual and forb species were found also on several treatments on the overflow range site. These high yields were found mostly on treatments applied in 1958, after the drought had begun. This response seems to be related more to a drought and

TABLE 1.—*Air-dry, herbage yields on overflow range sites on treatments applied in October 1957 and in October 1958. Yields averaged by year of treatment application, herbage component, year harvested, and treatment, 1958–62. Yields for most years of nonsignificant response omitted*

Year treated, herbage component, and year harvested	Yield by treatment [1]							
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N
	Pounds per acre							
TREATED IN 1957								
Western wheatgrass—								
Harvested in 1958	460c	470c	15d	430c	500bc	380c	620b	810a
Harvested in 1959	280c	480b	140d	490b	540ab	620ab	680a	620ab
Harvested in 1960	170d	150d	90d	370c	600ab	360c	500bc	650a
Harvested in 1961	40a	60a	140a	140a	100a	130a	170a	80a
Harvested in 1962	520ab	150e	610a	240de	280cde	410bc	390bcd	220e
All perennial grasses—								
Harvested in 1958	700bc	590c	30d	570c	720bc	680bc	820b	1140a
Harvested in 1959	350d	540bc	140e	490cd	570bc	620abc	720ab	770a
Harvested in 1960	240e	450cd	330de	550bc	830a	590bc	700ab	780a
Harvested in 1961	65a	80a	140a	150a	110a	190a	180a	80a
Annual and forb spp.—								
Harvested in 1958	10b	50b	1170a	20b	20b	50b	50b	30b
Harvested in 1959	40b	30b	1280a	50b	30b	30b	10b	110b
Harvested in 1960	50a	70a	320a	70a	70a	20a	230a	50a
Harvested in 1961	90a	120a	140a	120a	130a	90a	140a	80a
Harvested in 1962	500c	940ab	1160a	810abc	750bc	620bc	820abc	470c
TREATED IN 1958								
All perennial grasses—								
Harvested in 1959	450b	340bc	90e	170de	240cd	410b	380bc	640a
Harvested in 1960	220bc	350ab	150c	310ab	250bc	340ab	330ab	440a
Annual and forb spp.—								
Harvested in 1959	40b	30b	580a	60b	80b	140b	10b	170b
Harvested in 1960	60b	30b	430a	30b	70b	60b	10b	80b
Harvested in 1961	190a	80a	260a	80a	120a	140a	70a	160a
Harvested in 1962	790b	1110a	1150a	1120a	1070a	1140a	760b	1010a

[1] Yields by treatments within each year row when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

grazing interaction than to the range improvement treatments.

Silty Range Site

During the study, yields of blue grama were higher on the silty range site than on any other site (table 2). The silty range site and the dense clay range site were the two sites least responsive to the range improvement treatments studied.

On the silty range site, yields of western wheat. grass increased on only the seeding treatment. Where the range was seeded before the drought had begun, yields of western wheatgrass increased in the third and later years after seeding. Where the range was seeded after the drought had begun, yields did not increase until the last year of the study.

Yields of blue grama and of all perennial grasses, as a group, decreased significantly on the seeding treatment in the first year after seeding. Yields of blue grama increased on the 30N and 90N

TABLE 2.—*Air-dry, herbage yields on silty range sites on treatments applied in October 1957 and in October 1958. Yields averaged by year of treatment application, herbage component, year harvested, and treatment, 1958–62. Yields for most years of nonsignificant response omitted*

Year treated, herbage component, and year harvested	Yield by treatment [1]							
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N
	Pounds per acre							
TREATED IN 1957								
Western wheatgrass—								
Harvested in 1960	2b	[2] Tb	210a	10b	70b	30b	50b	10b
Harvested in 1961	10a	0a	50a	20a	20a	20a	10a	2a
Harvested in 1962	10b	0b	300a	[2] Tb	[2] Tb	60b	30b	30b
Blue grama—								
Harvested in 1958	190b	220b	10c	270ab	250ab	250ab	280ab	330a
All perennial grasses—								
Harvested in 1958	330a	320a	70b	390a	290a	350a	420a	490a
Annual and forb spp.—								
Harvested in 1958	10b	30b	860a	10b	5b	4b	20b	10b
Harvested in 1959	30b	20b	540a	80b	40b	70b	20b	60b
TREATED IN 1958								
Western wheatgrass—								
Harvested in 1962	80b	60b	240a	60b	50b	50b	80b	70b
Blue grama—								
Harvested in 1959	30b	50b	5c	80ab	90ab	80ab	100a	110a
All perennial grasses—								
Harvested in 1959	230a	170ab	40b	140ab	170ab	160ab	230a	160ab
Annual and forb spp.—								
Harvested in 1960	20b	20b	280a	70ab	40b	20b	60ab	50b
Harvested in 1961	50b	60b	450a	160b	110b	100b	90b	80b

[1] Yields by treatments within each year row when followed by the same letter on letters are not significantly different at the 5-percent level (Duncan *1955*).

[2] T=less than one-half pound per acre.

treatments in only the first year. No residual carryover effects were found.

Yields of annual and forb species increased significantly on the seeding treatment in the second and third year after seeding.

Clayey Range Site

Seeding was by far the most successful range improvement treatment on the clayey range site (table 3). The response of herbage to seeding was greater on this site than on any other site.

When the range was seeded before the drought had begun, yields of western wheatgrass increased as early as the second year after treatments had been applied, and yields of all perennial grasses, as a group, increased in the fourth and fifth years. In 1961, the year of severe drought, yields of all perennial grasses increased on only the seeding treatment and on only the clayey range site.

Where the range was seeded after the drought had begun, yields of western wheatgrass and of all perennial grasses, as a group, did not increase until the last year of the study. Yields of annual and forb species increased on the seeding treatment in all 4 years of the study.

In 1962, yields of all perennial grasses decreased on several treatments, and yields of annual and forb species increased on all treatments. These responses were probably due to a drought and grazing interaction.

TABLE 3.—*Air-dry, herbage yields on clayey range sites on treatments applied in October 1957 and in October 1958. Yields averaged by year of treatment application, herbage component, year harvested, and treatment, 1958–62. Yields for most years of nonsignificant response omitted*

Year treated, herbage component, and year harvested	Yield by treatment [1]							
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N
	Pounds per acre							
TREATED IN 1957								
Western wheatgrass—								
Harvested in 1959	10b	60b	240a	30b	8b	30b	10b	20b
Harvested in 1960	20b	100b	220a	30b	20b	70ab	10b	10b
Harvested in 1961	3b	20b	290a	20b	2b	0b	0b	20b
Harvested in 1962	0b	90b	440a	0b	1b	[2] Tb	0b	0b
Blue grama—								
Harvested in 1958	100de	140cd	20e	160cd	220bc	350a	200bc	280ab
All perennial grasses—								
Harvested in 1958	430a	420a	80b	440a	550a	590a	440a	500a
Harvested in 1961	80b	130ab	300a	80b	50b	90b	80b	110ab
Harvested in 1962	60b	250b	460a	180b	160b	80b	80b	140b
TREATED IN 1958								
Western wheatgrass—								
Harvested in 1962	80b	[2] Tb	470a	30b	0b	30b	0b	0b
All perennial grasses—								
Harvested in 1962	220b	50c	510a	140bc	50c	70bc	70bc	30c
Annual and forb spp.—								
Harvested in 1959	0b	30b	560a	30b	10b	[2] Tb	40b	30b
Harvested in 1960	130b	200b	480a	90b	220b	70b	160b	160b
Harvested in 1961	80b	130b	450a	60b	160b	180b	240ab	140b
Harvested in 1962	290c	690b	620b	590b	600b	680b	960a	760ab

[1] Yields by treatments within each year row when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).
[2] T = less than one-half pound per acre.

Dense Clay Range Site

Yields of western wheatgrass on the dense clay range site increased on only the 90N treatment (table 4), and in only the first year after application, where the treatment was applied before the drought had begun. No residual carryover effects were found.

Yields of western wheatgrass and of all perennial grasses, as a group, on the seeding treatment were significantly lower than yields on the grazing treatment until the third year after seeding. At no time during the study did yields of all perennial grasses increase on the seeding treatment.

Yields of annual and forb species increased significantly on the seeding treatment on the dense clay range site during the study. Where the range was seeded before the drought had begun, yields of annual and forb species increased only in the first year. Where the range was seeded after the drought had begun, yields of these species increased in all 4 years of the study.

In 1962, the year of above-normal moisture, a delayed response to the 90N treatment was found on this site. Yields of annual and forb species increased only where the 90N treatment had been applied after the drought had begun.

TABLE 4.—*Air-dry, herbage yields on dense clay range sites on treatments applied in October 1957 and in October 1958. Yields averaged by year of treatment application, herbage component, year harvested, and treatment, 1958-62. Yields for most years of nonsignificant response omitted*

Year treated, herbage component, and year harvested	Yield by treatment [1]							
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N
	Pounds per acre							
TREATED IN 1957								
Western wheatgrass—								
Harvested in 1958	250b	180bc	60c	230b	240b	220b	220b	560a
Harvested in 1959	290ab	280ab	100c	390a	350a	420a	140bc	430a
All perennial grasses—								
Harvested in 1958	440ab	380b	60c	300b	340b	410ab	370b	590a
Harvested in 1959	350a	440a	100b	400a	440a	490a	290a	490a
Annual and forb spp.—								
Harvested in 1958	0a	0a	270a	10a	1a	0a	3a	10a
Harvested in 1959	30b	60b	540a	140b	4b	2b	30b	20b
TREATED IN 1958								
Western wheatgrass—								
Harvested in 1959	290a	190ab	9c	230ab	230ab	270ab	200ab	290a
Harvested in 1960	220ab	200ab	7c	210ab	260a	260a	100bc	200ab
All perennial grasses—								
Harvested in 1959	310a	230a	9b	240a	270a	310a	270a	320a
Harvested in 1960	270ab	250ab	7c	320a	270ab	300a	150b	220ab
Annual and forb spp.—								
Harvested in 1959	10b	20b	420a	0b	2b	0b	10b	9b
Harvested in 1960	10b	10b	230a	4b	10b	10b	30b	20b
Harvested in 1961	20b	60b	460a	40b	60b	20b	80b	100b
Harvested in 1962	420b	350b	710a	380b	500ab	340b	410b	670a

[1] Yields by treatments within each year row when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

Crude Protein

The average crude protein content of total herbage was highest during the study on the dense clay range site and lowest on the overflow and silty range sites (tables 5 and 6). These responses appear to be an inherent feature of these sites or soils.

A significant interaction of sites or soils and treatment effects on protein content was found in the first year after treatment had been applied.

In the first year protein content increased on all treatments on the dense clay range site except on the rest treatment, but only where the treatments were applied before the drought had begun. On the other sites protein content increased on only the seeding and 90N treatments.

Where the treatments were applied after the drought had begun, protein content increased on only the seeding treatment on the overflow and dense clay range sites. On the silty range site protein content increased on only the seeding and 90N treatments.

Protein content increased on most treatments the first year after application, but not in subsequent years. In the second year after application, crude protein increased on only the seeding, pitting plus 30N, and 90N treatments, but only where the treatments were applied before the drought had begun.

TABLE 5.—*Crude protein content of total herbage ($N \times 6.25$) on treatments applied in October 1957 and in October 1958 and sampled in 1958 and 1959, respectively. Protein content averaged by year of treatment application, year of sample, range site, and treatment*

Year treated, year sampled, and range site	Crude protein content by treatment [1]								
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N	Average [2]
	Percent								
TREATED IN 1957									
Sampled in 1958 on—									
Overflow range site	7. 9c	9. 2bc	11. 6a	8. 2c	8. 8c	9. 6bc	9. 4bc	10. 4ab	[3] 8. 2b
Silty range site	6. 2c	7. 2c	14. 0a	7. 2c	7. 2c	8. 2c	7. 3c	10. 2b	[3] 8. 2b
Clayey range site	7. 0b	7. 4b	12. 0a	7. 9b	7. 6b	8. 4b	8. 8b	11. 2a	[3] 9. 1ab
Dense Clay range site	7. 4d	8. 0cd	11. 2a	9. 5abc	9. 6abc	9. 6abc	9. 2bc	10. 2ab	[3] 9. 6a
TREATED IN 1958									
Sampled in 1959 on—									
Overflow range site	7. 6b	8. 0ab	10. 5a	8. 2ab	8. 0ab	8. 6ab	7. 9ab	9. 1ab	[4] 8. 4b
Silty range site	7. 0c	7. 8bc	10. 3ab	8. 6bc	6. 7c	8. 9bc	8. 8bc	12. 0a	[4] 8. 7b
Clayey range site	7. 6a	8. 8a	9. 9a	7. 8a	9. 7a	10. 2a	10. 0a	7. 7a	[4] 9. 6ab
Dense Clay range site	9. 5b	10. 6ab	13. 0a	11. 0ab	9. 2b	11. 6ab	11. 8ab	11. 3ab	[4] 10. 4a

[1] Protein contents by treatments within each site row or within column of averages within each year of treatment application when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

[2] Column of averages shows averages during entire study.

[3] Five-year average, 1958–62.

[4] Four-year average, 1959–62.

TABLE 6.—*Crude protein content of total herbage ($N \times 6.25$) on treatments applied in October 1957 and in October 1958 and sampled annually through 1962. Protein content averaged by year of treatment application, year of sample, and treatment*

Year treated, year sampled	Crude protein content by treatment [1]								
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N	Average
	Percent								
TREATED IN 1957									
Sampled in 1958	7. 1e	8. 0d	11. 6a	7. 9d	7. 9d	8. 9c	8. 6cd	10. 4b	8. 8b
Sampled in 1959	7. 9c	8. 2c	9. 7a	8. 4bc	7. 9c	9. 3ab	8. 3bc	10. 1a	8. 7b
Sampled in 1960	7. 9a	7. 9a	7. 4a	7. 9a	7. 4a	7. 7a	7. 4a	8. 0a	7. 7c
Sampled in 1961	10. 8b	11. 0b	12. 6a	11. 4b	11. 1b	11. 0b	10. 3b	10. 9b	11. 2a
Sampled in 1962	7. 5a	7. 1abc	7. 8a	7. 2abc	7. 0abc	6. 5bc	6. 5bc	6. 2c	7. 0d
TREATED IN 1958									
Sampled in 1959	7. 9e	8. 4de	10. 0ab	9. 2bcd	8. 6cde	9. 8b	9. 5bc	10. 8a	9. 3b
Sampled in 1960	7. 9a	8. 5a	8. 6a	8. 3a	8. 0a	8. 7a	8. 4a	9. 2a	8. 5c
Sampled in 1961	10. 8b	10. 7b	12. 9a	10. 5b	10. 8b	11. 2b	11. 4b	11. 8ab	11. 3a
Sampled in 1962	7. 5bc	7. 9ab	8. 5a	6. 6c	7. 3bc	7. 3bc	7. 7ab	7. 6b	7. 6b

[1] Protein contents by treatments within each year row or within column of averages within each year of treatment application when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

In 1961, the year of severe drought, protein content was higher on the seeding treatment than on any other treatments, regardless of year of treatment application. Also, in 1961, the protein content was significantly higher than in any other year.

In 1962, the year of above-normal moisture, protein content was again higher on the seeding treatment, but only where this treatment was applied after the drought had begun. The protein content, on the average, was also lower in 1962 than in any other year. Also, in 1962, the protein content was significantly lower on the nitrogen treatments than on any other treatments on nearly all soils where nitrogen had been applied before the drought had begun.

Stocking Rates

Yields of western wheatgrass were substantially lower on heavily stocked range than on lightly stocked range (table 7). These low yields were most evident on the overflow and dense clay range sites where western wheatgrass was most abundant. These differences in yields of western wheatgrass resulted in similar but smaller differences in yields of total perennial grasses and in still smaller differences in yields of total herbage. These differences in yields between heavily and lightly stocked ranges were greatest in the early years of study and least in the drought year of 1961.

On heavily stocked range, where the range improvement treatments were applied before the drought had begun, yields of blue grama and of all perennial grasses, as a group, increased on both nitrogen treatments and the pitting plus alfalfa treatment. On lightly stocked range, yields of blue grama did not respond to any treatment.

Where the range improvement treatments were applied after the drought had begun, yields of blue grama and of all perennial grasses, as a group, decreased on most treatments. These reduced yields were more evident on lightly stocked range than on heavily stocked range. During the study, stocking rates did not influence yields of either western wheatgrass or annual and forb species.

TABLE 7.—*Average air-dry, herbage yields on treatments applied in October 1957 and in October 1958 for the years 1958–62 and 1959–62, respectively. Yields averaged by year of treatment application, herbage component, stocking rate, and treatment*

Year treated, herbage component, and stocking rate	Yield by treatment [1]								
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N	Average
	Pounds per acre								
TREATED IN 1957									
Blue grama with—									
Heavy stocking rate	70d	70d	5e	80cd	100bc	70d	110ab	140a	80a
Light stocking rate	80ab	90ab	1c	80ab	100ab	100ab	70b	110a	80a
All perennial grasses with—									
Heavy stocking rate	200de	190e	100f	240cde	270bc	250cd	310b	370a	240b
Light stocking rate	280b	310ab	230c	310ab	340a	320ab	320ab	340a	310a
TREATED IN 1958									
Blue grama with—									
Heavy stocking rate	50a	50a	1c	40ab	50a	50a	30ab	40ab	40a
Light stocking rate	60a	40b	3d	30c	40bc	30bc	40bc	20c	30a
All perennial grasses with—									
Heavy stocking rate	160ab	130bc	90d	150abc	140abc	180a	120bcd	120bcd	140b
Light stocking rate	220a	200abc	140d	160cd	170bcd	160cd	230a	210ab	190a

[1] Yields by treatments within each stocking rate row or within column of averages for each herbage component within each year of treatment application when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

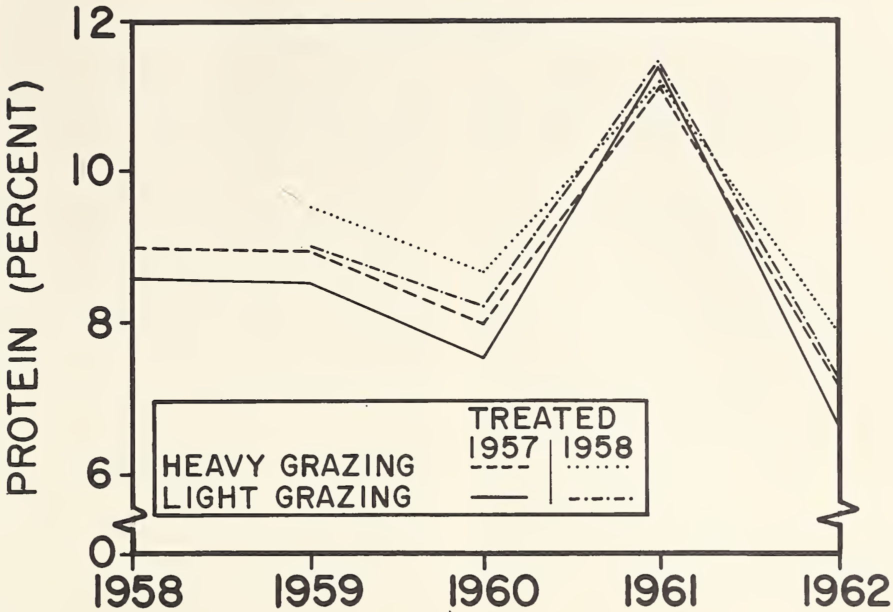

FIGURE 3.—Percent crude protein of total herbage during the period 1958–62, showing effects of treatment dates, stocking rates, and year of sample.

During the study the overall effects of heavy and light stocking rates on the protein content of herbage were not significant. However, the interaction between weather and stocking rates did significantly affect protein content. The protein content of herbage was slightly higher on heavily stocked range in all years except 1961, the year of severe drought (fig. 3), when protein content was higher on lightly stocked range.

Soil Nitrogen

In the fall 1962, at the end of the study period, soil nitrogen levels in the top 1 foot of soil were determined on all treatments on the heavily stocked silty range site. Increased levels of soil nitrogen were found on the rest, seeding, and pitting treatments where they were applied before the drought had begun (table 8). Where the treatments were applied after the drought had begun, no differences between treatments were evident.

The levels of soil nitrogen on this range site and stocking rate combination in 1962 were not well correlated with yields or protein contents of herbage. Yields of western wheatgrass and of annual and forb species increased in 1962 on the seeding treatment for both years of treatment application. The protein contents of herbage were not significantly different between any treatments.

TABLE 8.—*Available soil nitrogen in September 1962 on heavily stocked area of silty range site on treatments applied in October 1957 and in October 1958*

Year treated	Soil nitrogen by treatment [1]							
	Grazing	Rest	Seeding	Pitting	Pitting + alfalfa	Pitting + 30N	30N	90N
	Parts per million							
1957	92d	162abc	175ab	222a	138bcd	112cd	85d	112cd
1958	75a	88a	95a	92a	112a	112a	85a	150a

[1] Available soil nitrogen levels within each year of treatment application row when followed by the same letter or letters are not significantly different at the 5-percent level (Duncan *1955*).

DISCUSSION

The 90N treatment, applied only once, was initially the most successful of all treatments compared. It was followed closely by the 30N treatment.

On the overflow range site one application of nitrogen before the drought had begun increased yields of western wheatgrass and of all perennial grasses, as a group, for 3 consecutive years. Yields of western wheatgrass increased an average of 125 percent for the 90N treatment and 100 percent for the 30N treatment each year for the 3 years. Yields of all perennial grasses, as a group, increased an average of 110 and 75 percent each year for the 90N and 30N treatments, respectively. A similar residual carryover of nitrogen-induced yield increases was also shown by Black (*1968*). On the other sites, yields of western wheatgrass and of blue grama increased in only the first year.

Applications of nitrogen after drought had begun increased yields of all perennial grasses, as a group, on the overflow range site and yields of blue grama on the silty range site in only 1 or 2 years.

The 30N treatment applied on the overflow range site before the drought had begun was profitable. For a total fertilizer cost of $2.90 per acre (ammonium nitrate costs of $55 to $60 per ton) or $0.97 per acre per year, yields of western wheatgrass were doubled and yields of all perennial grasses, as a group, were increased an average of 75 percent per year for 3 years. This evaluation does not include the improved forage quality from the 20- to 50-percent increase in protein content.

Decreased yields of all perennial grasses, as a group, and decreased protein contents on the fertilizer treatments in 1962 on the overflow and clayey range sites indicate that the nitrogen fertilizers may have unfavorable residual effects on these sites following a drought. Continued fertilizer applications may prevent these decreases.

Over the long run, the most successful range improvement treatment was seeding western wheatgrass. On the silty and clayey range sites, where blue grama was most abundant, the seeding treatment decreased yields of blue grama and increased yields of western wheatgrass and of all perennial grasses, as a group. The plowing and disking of the seeding treatment effectively removed blue grama on the sites where it was most abundant. On these same sites yields of western wheatgrass increased more than on the other two sites.

On the overflow and dense clay range sites, where western wheatgrass was most abundant, seeding initially decreased yields of western wheatgrass and of all perennial grasses, as a group. These decreases were followed by increases in yields to the level of that of the grazing treatment. The seeding treatment increased protein contents on all sites in the first year after treatment, except on the clayey range site. Soil stirring from the plowing and disking with subsequent rapid release of soil nitrogen was no doubt responsible for the increased protein contents found on the seeding treatment.

On the clayey range site, the seeding treatment increased yields of all perennial grasses in the range of 130 to 700 percent after the first year. At average annual seeding costs of about $1.20 per acre per year (Neilsen *1967*, table 6; costs probably not changed since 1967), these represent a substantial economic return.

The increased yields of western wheatgrass from seeding as high as 100-fold in some years on the silty and clayey range sites provides a much longer grazing season in combination with blue grama than does blue grama alone. The effects of this longer grazing season and the higher crude protein content of herbage resulting from the seeding treatment are difficult to evaluate economically. However, they should contribute to increased economic return from the seeding treatment.

The seeding treatment also substantially increased yields of annual and forb species. The long period of subnormal precipitation after seeding was no doubt a major factor in these increases.

It is evident that establishment and growth of western wheatgrass during drought are slow on overflow and dense clay range sites, even though it is most adapted to these sites. Establishment and growth are far more rapid on silty and clayey range sites, even during drought. Thus, both the silty and clayey range sites in eastern Montana will support more western wheatgrass than is now generally present.

The range pitting treatments and combinations were moderately successful. These treatments had little effect on herbage yields and protein content on silty and dense clay range sites. However, when applied on the overflow range site before the drought had begun, these treatments increased yields of western wheatgrass and of all perennial grasses, as a group, during the second and third years after application.

Also, on the overflow range site, several pitting treatments reduced yields of western wheatgrass and of all perennial grasses, as a group, in 1962, the high moisture year following the drought. Apparently, the herbage on pitting treatments on this range site was not able to respond to high moisture following drought as well as the herbage on untreated range.

During the study, yields of all perennial grasses, as a group, were somewhat higher on the pitting plus alfalfa treatment than on the pitting treatment alone. Possibly the alfalfa plants contributed some nitrogen stimulus despite low establishment.

The rest treatment was the least effective treatment studied. Only in the second and third years after treatments had been applied did yields of perennial components increase on this treatment. However, protein content increased on the rest treatment in the first year after application, but only where the treatment had been applied before the drought had begun.

The increased yields of annual and forb species on all treatments, except the grazing treatment, on both the overflow and clayey range sites in 1962 seem clearly related to grazing. On both sites the continued grazing through 1961 probably reduced plant populations and seed sources sufficiently to prevent a subsequent increase in response to the abundant moisture and low plant cover that was present after the drought.

During the study, herbage yields showed little differential response to treatments between heavily and lightly stocked ranges. Apparently, the native herbage on these ranges responds equally well to range improvement treatments, regardless of past stocking treatments.

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